

hornblende, but the angles of cleavage (which, however, is in no case very well defined) and of extinction make it more probable that the mineral is augite. There are two or three crystals of a slightly greenish colour, which show the characteristic form and cleavage of augite, and one which in all respects better agrees with hypersthene. The ground-mass consists of fairly numerous, lath-shaped crystallites of a plagioclasic felspar, prisms of augite (?), often darkened with ferrite, granules of opacite and ferrite, and possibly in some cases flakes of mica. These are scattered in what may be a glassy base, but it is so densely crowded with extremely minute acicular crystallites (colourless, probably felspar), and with a minute dust (ferrite in the browner streaks, opacite in the darker) that, as the slide is rather thicker than usual, I cannot be quite sure. Although, to the unaided eye, and even when examined with low powers, this rock appears to differ considerably from (5) and (8), yet with high powers the resemblance becomes much closer, so that we may, I think, confidently refer it to the same group, and regard it as merely a more slaggy variety.

It follows, then, from the above examination that the rocks which form the actual peak of Antisana are augite-andesites, containing at any rate occasionally hypersthene, and to the same group belongs, though perhaps it is slightly more basic, the rock of the great lava stream which has descended to Antisanilla, while the pitchstones of Quebrada de Urcucuy must be representatives of a group with a higher percentage of silica, *i.e.*, rhyolites or dacites, probably the former.

IV. "The Variation of Stability with Draught of Water in Ships." By F. ELGAR, Professor of Naval Architecture in the University of Glasgow. Communicated by Professor Sir WILLIAM THOMSON, F.R.S. Received March 6, 1884.

(Abstract.)

Of all the properties possessed by a ship none is more vital to her safety and efficiency than that of stability. At the same time none is dependent for its existence and amount upon so many or such diverse and variable circumstances as it. The stability of a ship, both as regards moment and range, is affected not only by the position of her centre of gravity, which largely depends upon stowage, but also by draught of water. If the centre of gravity be kept fixed in position at various draughts of water, the stability will still vary very considerably with the draught, and often in a manner that contains elements of danger.

The usual practice in investigating a ship's stability is to calculate a curve of metacentres, and one or more curves of stability at certain

fixed draughts of water and with given positions of centre of gravity. The curve of metacentres gives the height at all draughts of water above which the centre of gravity cannot be raised without making the ship unstable when upright, and causing her to lie over more or less to one side. The ordinates of the curve of stability represent the lengths of the righting arms, which, multiplied by the weight of the ship, give the righting moments at all angles of inclination from the upright. The stability of numerous vessels, both of the Royal Navy and Mercantile Marine, have been investigated in this manner for certain draughts of water, and a great amount of information obtained respecting the variation of stability with inclination at such draughts, and the angle at which the stability vanishes in many classes of ships. The peculiar dangers attaching to low freeboard, especially when associated with a high centre of gravity, have been fully discussed and made known.

Curves of stability having been chiefly constructed for deep and moderate draughts, the character of the stability which is often to be found associated with very light draught, appears to have hitherto escaped attention. As a matter of fact, light draught is often as unfavourable to stability as low freeboard, and in some cases more so. The general opinions that have till recently prevailed upon the subject appear to have been based upon a vague impression that so long as a vessel has a high side out of water, and any metacentric height, she will have great righting moments at large angles of inclination and a large range of stability. It was shown at the "Daphne" inquiry, held by Sir E. J. Reed, in July last, that these opinions largely prevailed and were erroneous.

It fell to my lot to make some investigations respecting the stability possessed by the "Daphne" at the time of the disaster which happened to her, and to give evidence respecting the same. I afterwards pointed out, by way of explanation of my evidence, in a letter to the "Times" of the 1st September last, some of the considerations which obviously apply to light draught stability. The first, which so far as I am aware had never before been stated, is that any homogeneous floating body which is symmetrical about the three principal axes as the centre of gravity—such as a rectangular prism or an ellipsoid—will have the same moment of stability at equal angles of inclination, whether floating at a light draught with a small volume below water, or at a deep draught with a similar volume above water. For instance, if a homogeneous prism of symmetrical cross-section 5 feet high float at a draught of water of 1 foot, it will then have precisely the same moment of stability at equal angles of inclination, and consequently the same curve of stability throughout, as if it were loaded—without altering the position of the centre of gravity—till it had 4 feet draught of water, and 1 foot of freeboard. From this it

follows that, in such elementary forms of floating bodies, lightness of draught has the same effect upon stability as lowness of freeboard; and if a low freeboard is unfavourable to stability, so also, and precisely to the same extent, is a correspondingly light draught of water. This proposition can be made still more general, as it applies to homogeneous bodies of any form of cross-section which revolve about an horizontal axis fixed only in direction. From this may be deduced the results given by Atwood in his papers read before the Royal Society in 1796 and 1798 respecting the positions of equilibrium and other peculiarities connected with the stability of floating bodies.

In considering the stability of a ship at various draughts of water, and comparing it with that of the class of figures above described, modifications require to be made for the departure from symmetry of form, and for the extent to which the vertical position of the centre of gravity differs from what it would be if the external surface enclosed a homogeneous volume. This has been attempted in the present paper, and curves of stability, which I call cross curves, have been given for various geometrical forms of floating bodies, and also for a large passenger steamer of ordinary type, showing how the stability varies with draught of water at constant angles of inclination. In dealing with these cross curves of stability the curves of righting moments require to be constructed, and not merely curves of lengths of righting arm. The ordinary curve of stability is usually made for lengths of righting arm, because the displacement is constant, and the same curve therefore gives upon different scales, either lengths of righting arm or righting moments. In the cross curves of stability, however, such as are now being dealt with, draught, and therefore displacement, is one of the variable quantities, and curves of righting moments are of a very different character from curves of righting arm. The curves given in the figures are therefore, in all cases, curves of righting moments. Complete cross curves for a ship, from which ordinary curves of stability can immediately be obtained for any draught of water and position of centre of gravity, can be constructed in a few days with the aid of Amsler's mechanical integrator.

The main object of this paper is to show the necessity of regarding the stability of a ship from the point of view of variation of righting moment with draught of water, the angle of inclination being constant, instead of from that of variation of righting moment with angle of inclination, the draught being constant, as is usually done; or rather of considering the subject from both points of view instead of almost exclusively from the latter. It also shows that it is necessary to investigate more fully than has formerly been done, the moments and range of stability of ships and other structures that may be intended to float at very light draughts of water.